Tropical Cyclone Diurnal Cycle As Seen By TRMM

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Background

With lack of suitable cases for the intended analysis of HIRAD+HIWRAP+HAMSR data, we've had to turn to an alternate topic…

Dunion et al. have been showing interesting patterns of Tropical Cyclone cloud-top evolution as a function of the diurnal cycle

- Pulse of cooling cloud tops propagates outward, with warming cloud tops behind
- Pulse in inner core (200 km) near sunset
- Outward propagation ~5-10 m s-1
- Pulse is in 300-600 km region by late morning through late afternoon, with inner core cloud tops having warmed

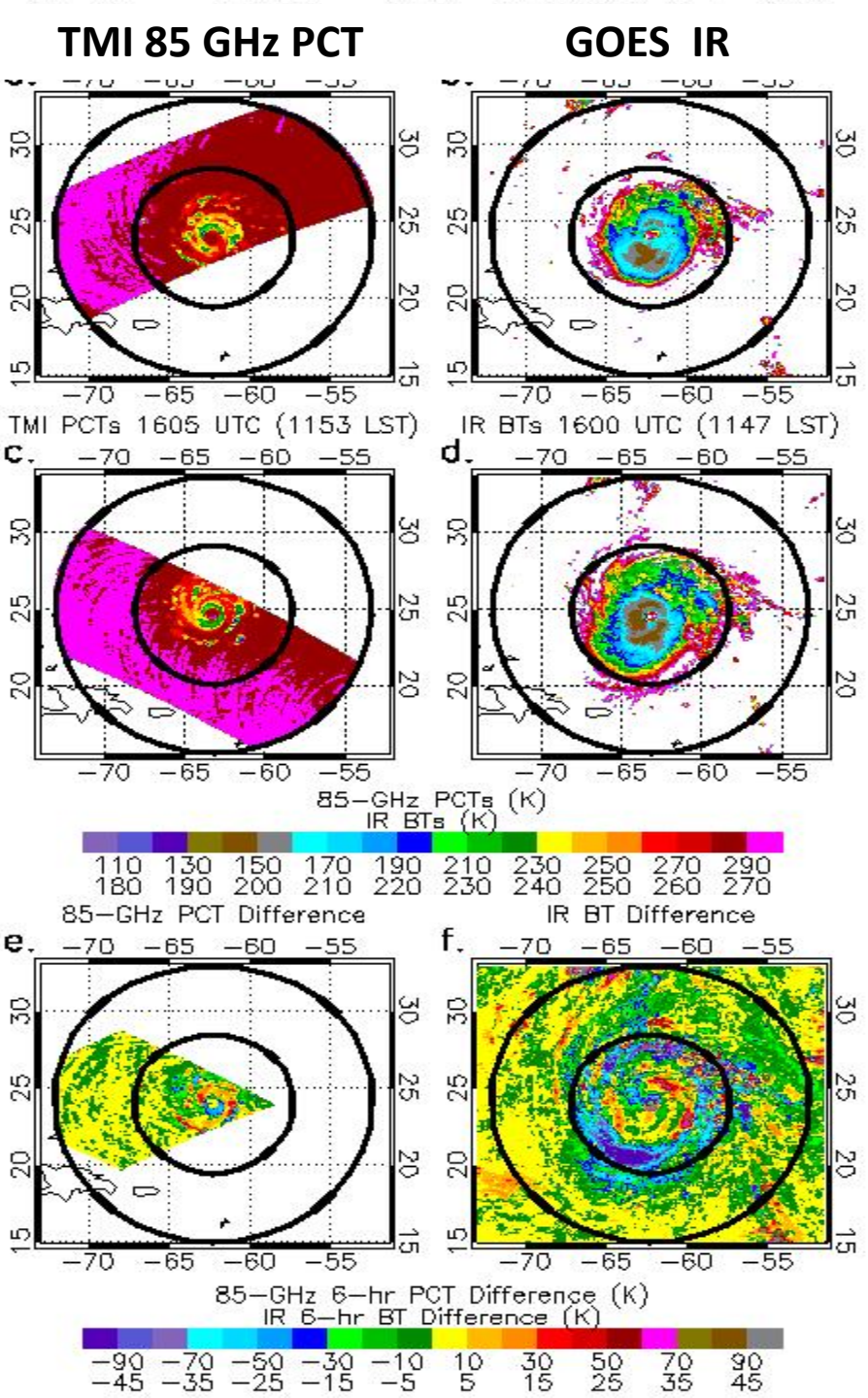
Is this a cloud-top level phenomenon, or connected through lower levels? Can TRMM PR and TMI address this?

TB Difference Maps, like Dunion's neat IR sequences, didn't work very well from Microwave overpasses.

Inter-sensor differences (footprint size, frequency, calibration) complicate time series built from TMI+SSMI+AMSR (or others)

TMI sometimes views the same storm multiple times a few hours apart, but the area with overlap between those observations (left column) is limited.

No firm conclusions using this approach. *The MI sample, with irregular timing between overpasses, is more suited for building composites.*

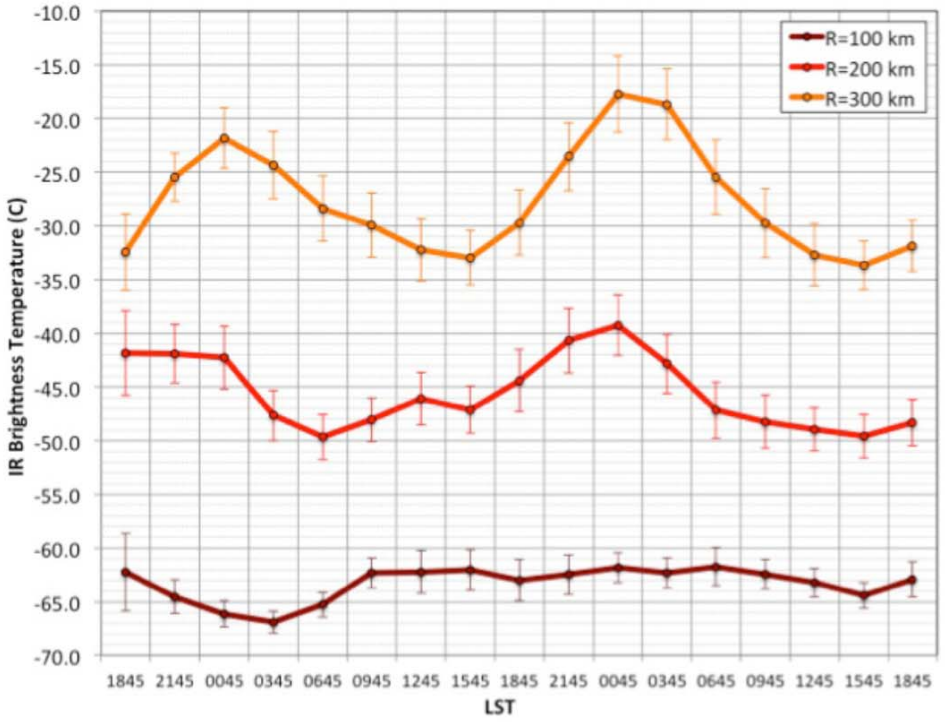


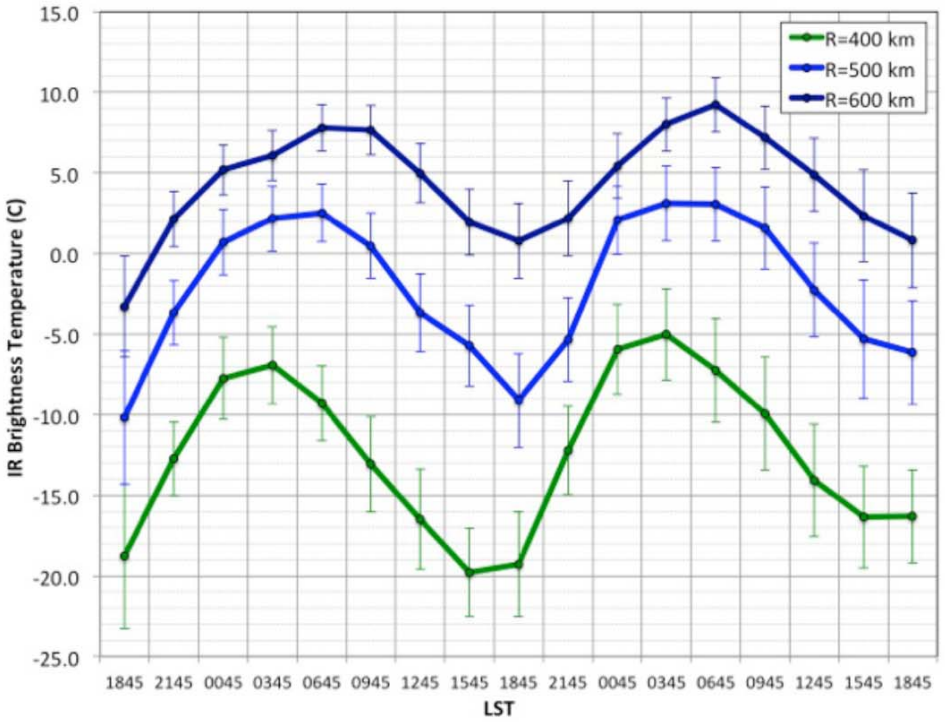
Top:
~0530 LST

Middle:
~1200 LST

Bottom:
Difference field

Mean IR TB's from Dunion et al.





Broad Minimum and Maximum propagate outward with time of day

200 km Radius: 0645-1845 LST Minimum, 0045 LST Maximum

300 km Radius: 1245-1845 LST Minimum, 0045 LST Maximum

400 km Radius: 1545-1845 LST Minimum, 0345 LST Maximum

500 km Radius: 1845 LST Minimum, 0345-0645 LST Maximum

600 km Radius: 1545-2145 LST Minimum, 0645-0945 LST Maximum

TMI Rain Coverage in Atlantic Tropical Cyclones

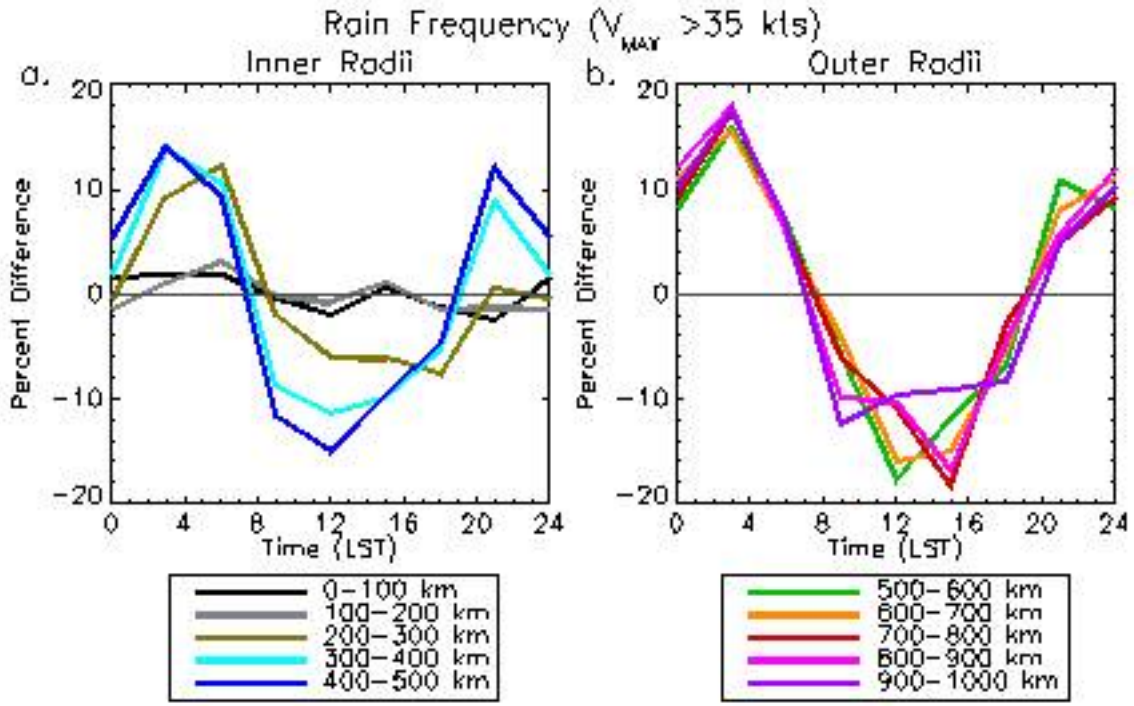
Fraction of pixels with rain rate > 0 in each annulus (and probability of rain > 50%)

Amplitude (%) of departure from daily mean is plotted

0-200 km: No diurnal cycle

200-300 km: Peak near sunrise at 0600 LST, broad minimum during afternoon 1200-1800 LST

300-1000 km: Overnight peak between 2100 - 0300 LST, broad daytime minimum 0900-1800 LST



- No obvious outward propagation with time
- Minimum rain coverage during time of colder composite IR TB, suggesting an expansion of the non-raining cirrus shield into the daytime

TMI Rain Coverage in Atlantic Hurricanes

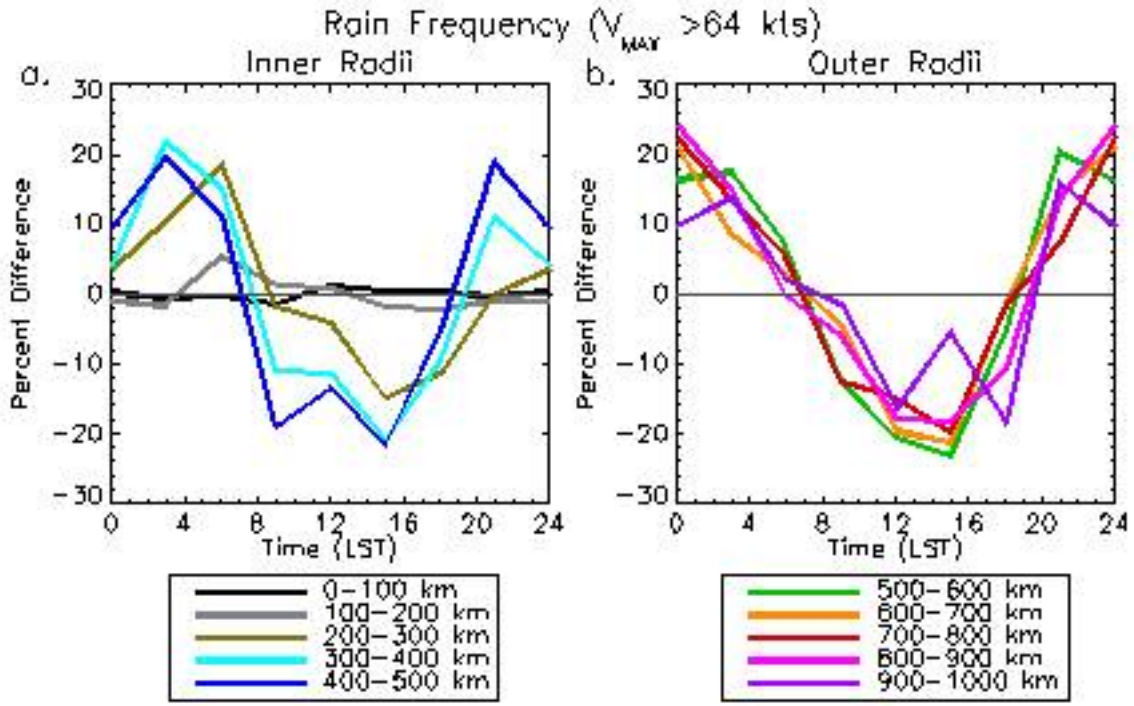
Fraction of pixels with rain rate > 0 in each annulus (and probability of rain > 50%)

Amplitude (%) of departure from daily mean is plotted

Very similar result for Hurricanes as for TS+Hurricanes

300-600 km: Overnight peak between 2100 - 0300 LST, broad daytime minimum 0900-1500 LST

600-1000 km: Sharper peak near midnight (but very little rain at this distance in the first place)



- No obvious outward propagation with time
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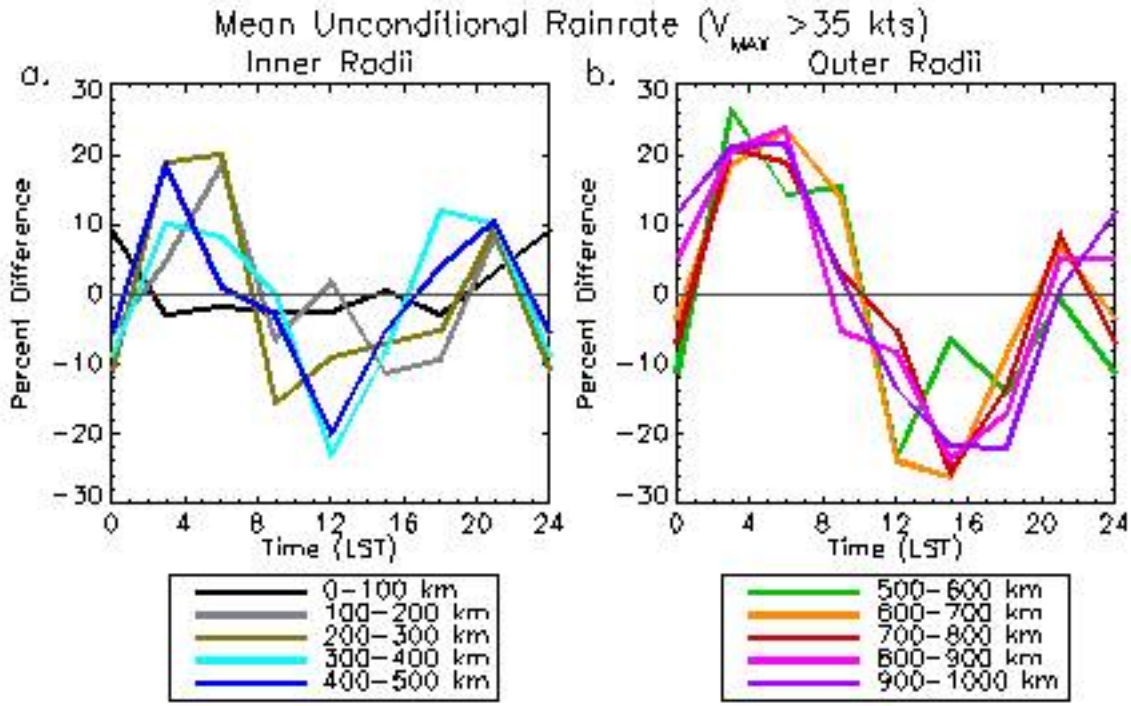
TMI Rain Rate in Atlantic Tropical Cyclones

Unconditional mean rain rate, includes the rain-free regions

Amplitude (%) of departure from daily mean is plotted

Generally similar to rain coverage plots, but noisier

Some variability at smaller radii, peaking at 0000 LST (0-100 km) and 0600 LST (100-200 km).



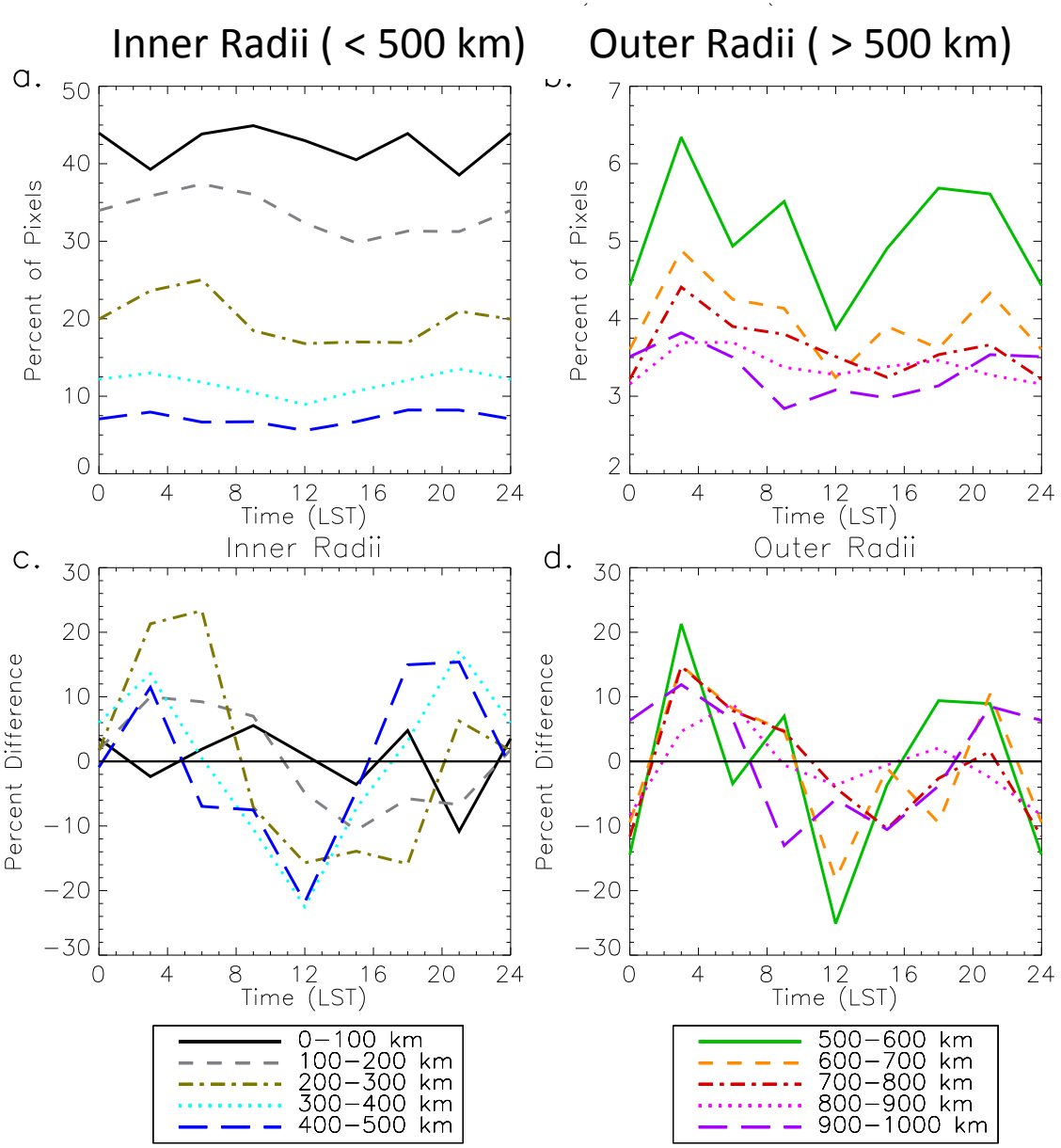
- No obvious outward propagation with time
- Minimum rain rates during time of colder composite IR TB, suggesting an expansion of the non-raining cirrus shield into the daytime

PR Echo Coverage in Atlantic Tropical Cyclones

Top:
Percentage of pixels with at least 20 dBZ echo at 2 km altitude, in each annulus

Bottom:
Amplitude (%) of departure from daily mean

Generally similar to TMI plots, but 100-200 km early-morning peak from 0300-0900 LST is more evident



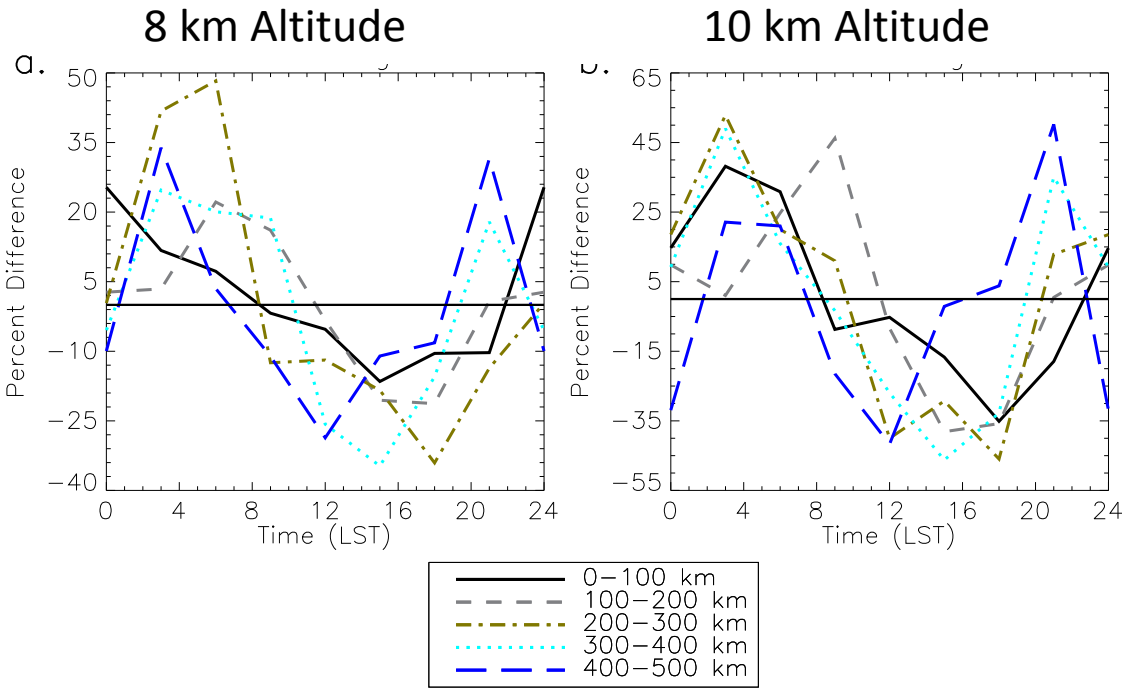
PR Echo Coverage in Atlantic Tropical Cyclones

Fraction of pixels with at least 20 dBZ echo at 8 km and 10 km altitudes, in each annulus

Amplitude (%) of departure from daily mean is plotted

At high altitudes, even a weak signal in the inner core can be seen, peaking late night – early morning, with minimum during late afternoon – early evening

Otherwise trends are generally similar to those at low altitudes



- Most of these plots have had a peak at 2100, relative minimum at 0000, then another peak at 0300.
- Not ready to say if that is a true double-peak, or sampling noise superimposed on a single broad peak.

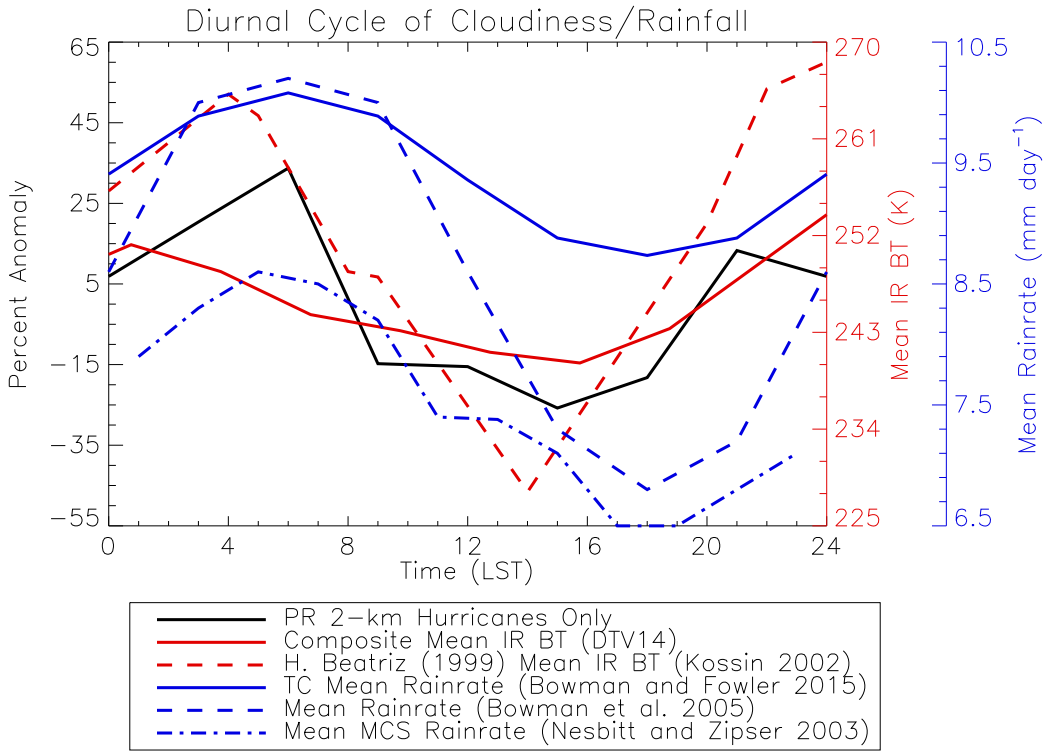
Rain and Cloud Coverage in Atlantic TCs

Comparison of these TRMM results with literature

200-300 km annulus plotted; most other annuli behaved similarly

Rain Coverage is out of phase with coldest mean IR brightness temperatures

Bowman and Fowler (2015) use TMPA – afternoon minimum is shifted a little later



TC Rain diurnal cycle generally similar to that for tropical oceans.

Summary and Caveats

TRMM Microwave Imager (TMI) and Precipitation Radar (PR) used to construct composites of Tropical Cyclone Diurnal Cycle

Case-by-case time series analysis does not give robust results, due to irregular, sporadic sampling from LEO.

- Adding other sensors (SSMI, AMSR-E) could help, but inter-sensor calibration, varying footprint sizes, and frequency differences complicate matters

Composites have similar trends in low level rain and upper level echo coverage.

- ***Overnight peak, afternoon minimum***

TC Diurnal Cycle of rain similar to tropical oceans (not specific to TCs)

Summary and Caveats

Peak rainfall is out of phase with coldest cloud tops

- ***Rain peaks overnight, with mean IR relatively warm***
- ***Rain minimum in afternoon, while mean IR at its coldest***

No obvious outward propagation in composites of rain rate or echo coverage.

- But similar to Dunion et al.'s IR results, diurnal cycle is weakest at innermost radii.

Emphasis here is on composite mean rain rate, mean radar echo coverage, mean IR brightness temperature as a function of Time of Day

- Dunion has shown striking features of *difference* fields in the IR – basically, time derivatives. The irregular temporal sampling makes such analyses difficult using microwave.